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DEVICE AND METHOD FOR PLATING
[Mekkisochi oyobi mekki hoho]

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[Claims] /546*

[Claim 1] Device for plating comprising a disk type rotary electrode rotating to circumferential direction, on one side of which a sample is fitted, and an anodic electrode provided against the described one side are arranged in a plating solution, so that electroplating is executed by energizing between these electrodes;

the device for plating comprises (1) a cylinder body positioned on a rotary axial line of said cathodic electrode, inside of which plural cylindrical inner walls are provided coaxially, and (2) the plating solution supplied from the respective spaces in the cylinder body to the described side of rotary electrode.

[Claim 2] Device for plating comprising a disk type rotary electrode rotating to circumferential direction, on one side of which a sample is fitted, and an anodic electrode provided against the described one side are arranged in a plating solution, so that electroplating is executed by energizing between these electrodes;

the device for plating comprises (1) a cylinder body-sectionally pie-shaped column having a plurality of gutter-like inner walls formed coaxially is continuously provided around the rotary axial line of said cathodic electrode, providing the arrangement allowing the inner column diameter to be different from the inner diameter of adjacent column, and (2) the plating solution supplied from the

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respective spaces in the cylinder body to the described side of rotary electrode.

[Claim 3] Plating method utilizing the plating device according to Claim 1, wherein the plating solution supply quantity supplied into the spaces in the cylinder is gradually increased from the inner side of the cylinder towards the outer side of the cylinder.

[Claim 4] Plating method utilizing the plating device according to Claim 2, wherein the plating solution supply quantity supplied into the spaces in the cylinder is gradually increased from the inner side of the cylinder towards the outer side of the cylinder.

[Detailed Explanation of this Invention]

[0001] [Industrial Field]

This invention pertains to a plating device for positioning a cathodic electrode and anodic electrode in a plating solution for conducting electroplating.

[0002] [Conventional Technology]

Electroplating is used for manufacturing magnetic devices and electric thin film elements for years. When applying precise plating to a wafer with electroplating, the stirring, temperature, current density, and pH of the plating solution must be strictly controlled. Particularly, when plating an alloy or the like for the purpose of producing a functional film, the film composition or the like significantly affects the characteristic. Therefore, more precise control is needed for bath plating which is highly sensitive to the

changes of plating condition and causes composition fluctuation. For example, NiFe alloy plating used for thin film magnetic head or the like belongs to the abnormal eutectoid type, easily depositing Fe compared with Ni, resulting in compositional fluctuation sensitively corresponding to the change of plating condition.

[0003] Among various plating conditions, the condition of creating a uniform flow of the plating solution on the wafer surface with excellent reproducibility is difficult to maintain without causing fluctuation. As a device capable of providing this condition, a paddle type reciprocal motion stirring plating device was reported. This device is equipped with a paddle type stirrer providing forward/backward movements at a uniform speed at the center part of the plating vessel so as to create layered flows of plating solution on the cathode substrate mounted with a wafer, with the reciprocal movements of the stirrer (refer to US Patent No. 4102756). Moreover, in addition to this device, an electrolysis plating vessel was reported (Pat. No. 62-207895). This method provides flow paths formed by two wall materials fixed to create a flow of plating solution, and the plating solution is sent from the lower side of the flow path towards the upper side to cause the plating solution to overflow from the upper end so as to create layered flows of plating solution on the cathodic electrode to which a wafer is mounted. Furthermore, as another device (Pat. No. 2-225693), with a cup type injection plating device which introduces plating solution from the

inlet at the lower surface, making the plating solution overflow from the comb-like part, a simply structured rectifier is placed at the upper part of the inlet to control the plating solution flow, and by rotating the cathodic electrode having a wafer, the entire plating solution flow is made uniform.

[0004] [Problems to be Solved by this Invention]

The abovementioned paddle type reciprocal movement stirring plating device and electrolysis plating vessel cannot create layered flows for the entire flow paths of the plating solution. Moreover, with the cup type injection plating device which rotates a cathodic electrode, although the cathode rotation can provide uniform flow of plating solution from the center part towards the outer side of the cup, since the plating solution flows while providing a plating reaction from the center part towards the outer side of the cup, the characteristic (e.g., concentration) of the plating solution changes from the center part towards the outer side. In addition, a simply structured rectifier which cannot control the subtle flow control on the wafer is not suitable for alloy plating or the like having the sensitivity of compositional changes to the fluctuation of the flow of the plating solution.

[0005] This invention was developed considering the abovementioned background. The object of this invention is to provide a plating device and method which can form a plating film having a precisely uniform film quality, composition, and film

thickness by suppressing the change of the characteristic (e.g., concentration) of the plating solution flowing along the cathodic electrode when a rotary cathodic electrode is used for plating.

[0006] [Method to Solve the Problems]

As the first plating device, this invention provides a device for plating comprising a disk type rotary electrode rotating to circumferential direction, on one side of which a sample is fitted, and an anodic electrode provided against the described one side are arranged in a plating solution, so that electroplating is executed by energizing between these electrodes; wherein the device for plating thereof comprises (1) a cylinder body positioned on a rotary axial line of said cathodic electrode, inside of which plural cylindrical inner walls are provided coaxially, and (2) the plating solution supplied from the respective spaces in the cylinder body to the described side of rotary electrode. /3

[0007] As the second device, this invention provides a device for plating comprising a disk type rotary electrode rotating to circumferential direction, on one side of which a sample is fitted, and an anodic electrode provided against the described one side are arranged in a plating solution, so that electroplating is executed by energizing between these electrodes; the device for plating thereof comprises (1) a cylinder body inside of which a cross-sectionally pie-shaped column having a plurality of gutter-like inner walls formed coaxially is continuously provided around the rotary axial

line of said cathodic electrode, providing the arrangement allowing the inner column diameter to be different from the inner diameter of adjacent column, and (2) the plating solution supplied from the respective spaces in the cylinder body to the described side of rotary electrode.

[0008] The first plating method of this invention is a method of plating using the plating device according to the Claim 1, providing the characteristic that the supply quantity of the plating solution in the spaces of the cylindrical body is made greater from the inner side towards the outer side of the cylindrical body.

[0009] The second plating method of this invention is a method of plating using the plating device according to the Claim 2, providing the characteristic that the supply quantity of the plating solution in the spaces of the cylindrical body is made greater from the inner side towards the outer side of the cylindrical body.

[0010] [Operation]

With the first plating device of this invention, as the cathodic electrode rotates, the plating solution flows evenly from the center part towards the outer circumference with the rotation of the cathodic electrode. In this case, the plating solution flows while providing the plating reaction, causing the changes of characteristics, such as concentration, of the plating solution. However, as the plating solution flows from the center part towards the outer circumference, a new plating solution is supplied from each

space in the cylinder, thereby making the characteristics, such as concentration, of the plating solution flowing along the cathodic electrode uniform from the center part towards the outer circumference.

[0011] With the second plating device of this invention, as the case of the first plating device, while the plating solution flows from the center part towards the outer circumference, a new plating solution is supplied from each space in the cylinder, thereby allowing the characteristics, such as concentration, of the plating solution flowing along the cathodic electrode to become uniform from the center part towards the outer circumference. Furthermore, since the inner wall diameters of the adjacent columns in the cylindrical body are made differently, plating solutions supplied to the cathodic electrode from the adjacent cylindrical spaces arrive at the different locations of the cathodic electrode in the diameter direction. Hence, the characteristics, such as concentration, of the plating solution flowing along the cathodic electrode becomes more uniform from the center part towards the outer circumference.

[0012] When plating is performed using the first plating device, if the plating solution supply quantity of the inner space is greater than that of the outer space in the cylindrical body, the plating solution supplied from the outer space in the cylindrical body may not reach to the cathodic electrode due to the interference of the flow of the plating solution from the center part towards the outer

peripheral part along the cathode. With the first plating method of this invention, the supply of plating solution is arranged to increase from the inner side towards the outer side of the cylindrical body. Therefore, the plating solution supplied from the spaces at the outer side in the cylindrical body can reach the cathodic electrode without being blocked by the plating solution flowing along the electrode.

[0013] When the plating is performed using the second plating device described above, if the plating solution supply quantity of the inner space is greater than that of the outer space in the cylindrical body, the plating solution supplied from the outer space in the cylindrical body may not reach the cathodic electrode due to the interference of the plating solution flowing from the center part towards the outer peripheral part along the cathode. With the second plating method of this invention, the supply of plating solution is arranged to increase from the inner side towards the outer side of the cylindrical body. Therefore, the plating solution supplied from the outer side space in the cylindrical body can reach the cathodic electrode without being blocked by the plating solution flowing along the electrode.

[0014] [Operational Example]

Hereafter, this invention is more practically explained with the operational examples by referring to figures. Fig. 1 is a cross-sectional diagram illustrating the structural model of the plating

device of this invention. Fig. 2 is a cross-sectional diagram of the plating vessel model of the device shown in Fig. 1.

[0015] In the figure, item 1 denotes a plating vessel made of an acrylic resin. This plating vessel 1 is provided coaxially with an inner vessel **12** having steps and a bottom, in a cylindrical outer vessel **11** sharing the bottom with the inner vessel **12**, wherein the outer diameter of the upper end **12a** of the inner vessel **12** is arranged greater than the rest of the outer diameters of the main body **12b** of the vessel **12**. A plurality of coaxial cylindrical inner walls **121**, **121**,... are provided in the main body **12b** of the inner vessel **12** for separating the space in the main part **12b** of the inner vessel **12** into a central columnar space **122** and a plurality of surrounding cylindrical spaces **123**, **123**,... Furthermore, each of inner walls **121**, **121**,... is made wider for a specific amount towards the upper end.

[0016] A plating solution having it temperature and concentration controlled is stored in an adjustment vessel **2** and guided into the inner vessel **12** from the bottom of each columnar space **122** and cylindrical spaces **123**, **123**,... through a flow-out pipe **21** having a pump **P** in the middle and guiding pipes **22**, **22**,... which are formed by branching out from the flow-out side of the pump **P** of the flow-out pipe **21** and contain respective flow quantity control valve **23**, **23**,... in the middle. Moreover, the plating solution guided into the inner vessel **12** overflows from the inner vessel **12**

and is collected in the space between the outer vessel **11** and inner vessel **12**. The collected plating solution is arranged to flow back into the adjustment vessel from the bottom of the space through a guide pipe **24**.

[0017] A rotary electrode **3** which is a disk-like cathodic electrode is positioned at the upper part of the inner walls **121**, **121**,... in the upper end **12a** of the inner vessel **12**. Moreover, net-like Ni anodic electrodes **4**, **4**,... supported by metallic rods **40**, **40**,... fixed at the bottom of the inside of the cylindrical spaces **123**, **123**,... excluding the lower section space and outermost space of the columnar space **122** and are positioned parallel to the rotary electrode **3**. Since the abovementioned anodic electrodes **4**, **4** are net-like, the plating solution can pass though the electrodes **4**, **4**. The metallic rod **40** is electrically connected to the negative /4
terminal of the DC power supply **6**, and the anodic electrode **4** is connected to the negative terminal of the DC power supply **6** through the metallic rod **40**.

[0018] A rotary shaft **30** (made of stainless) of rotary electrode **3** is mounted at the center of the upper face of the rotary electrode **3**. The rotary shaft **30** is made to rotate axially by a servo motor **5**, and the rotary electrode **3** is designed to rotate around the axial rotation of the rotary shaft **30**. Furthermore, a shaft reception part **13** positioned at the upper part of the plating vessel **1** for supporting the rotary shaft **30** is provided in the halfway of the

rotary shaft 30 in the longitudinal direction. In a cylindrical bearing case 130, the shaft reception part 13 equipped with a ball bearing 131 supporting the rotary shaft 30 and Teflon O-rings 132, 132, 132, 132 formed as two levels respectively above and below the ball bearing 131 for preventing corrosion. Thus, the shaft reception part 13 prevents eccentricity of rotary electrode 3 at the time of rotation.

[0019] Moreover, a phosphorous bronze brush 7 connected to the positive terminal of the DC power source 6 for transmitting an electric current from the DC power supply 6 to the rotary shaft 30 and an electricity transmission copper pipe 8 into which the rotary shaft 30 is inserted in such way so as to allow the outer circumference of the shaft 30 to contact the brush 7 are placed between the shaft reception part 13 and servo motor 5 in the axial direction of the rotary shaft 30. With this configuration, the rotary electrode 3 can be electrically connected to the positive terminal of the DC power source 6 through the rotary shaft 30, copper pipe 9 for transmitting electricity and brush 7. The section of the rotary shaft 30 where the copper pipe 8 for electric transmission and the part to be mounted to the rotary electrode 3 excluding the electrically conducted area are insulated with a Teflon film for corrosion prevention.

[0020] Fig. 3 is a diagram illustrating the back face of the rotary electrode 3. Fig. 4 is a cross-sectional diagram illustrating

the enlarged essential part of the rotary electrode 3. The rotary electrode 3 has a conductive plate **32** having the diameter equal to the disk-shaped resin wafer holder **31**, formed on the lower face of the disk-shaped resin wafer holder **31**. The center of a conductive plate **32** is electrically connected with the rotary shaft **30**. Square holes **310**, **310**,..., each having a diameter smaller than the diameter of the wafer holder **31**, are formed on the wafer holder **31**, being equally distributed at every 90 degrees on two different concentric circles. Moreover, square holes **320**, **320**,..., each having a diameter smaller than the diameter of the square holes **310** provided to the wafer holder **31**, are formed through the conductive plate **32**, being equally distributed at every 90 degrees on two different concentric circles. In this case, the wafer holder **31** and conductive plate **32** are specifically mounted so as to make holes **310**, **310**,... aligned to the holes **320**, **320**,... Moreover, a Teflon film **321** is masked at the center of the lower surface of the conductive plate **32** and at the outer edge, etc. (area filled with slanted lines in the figure) which are insulated from the plating solution. Then, wafers **9**, **9**,... are inserted into the holes **310**, **310**,... of the wafer holder **21** in such way that wafers **9**, **9**,... can be supported by the edges of holes **320**, **320**,.... The wafers **9**, **9**,... inserted into respective holes **310**, **310**,... of the wafer holder **31** expose their lower faces at the lower surface side of the rotary electrode 3 from the holes **320**, **320**,... of the conductive plate **32**. Moreover, the area of the conductive plate,

contacting the wafer **9**, and area not coated with a Teflon film **321** are gold-plated to prevent them from dissolving in the plating solution.

[0021] Moreover, as shown in Fig. 4, a screw hole **311** is formed at the respective upper part of the square hole **310** of the wafer holder **31**, and when the wafer **9** is inserted into the hole **310** of the wafer holder **31**, a buffering O-ring **312** is mounted onto the wafer. Then, by inserting the circular lid **313** into respective holes **311**, the wafer **9** can be mounted inside of the holes of the wafer holder **31**.

[0022] When plating using the plating device configured as described above, the plating solution is guided into the columnar space **122** and cylindrical spaces **123**, **123**,... of the inner vessel **12**, thereby allowing the rotary electrode **3** to be rotated by the servo motor. The plating solution guided into the columnar space **122** and cylindrical spaces **123**, **123**,... flows as shown in Fig. 5. Fig. 5 is a diagram illustrating the flow of the plating solution in the inner vessel **12**. As shown with the arrow in the figure, the plating solution flows from the lower area towards the upper areas in the columnar space **122** and cylindrical spaces **123**, **123**,... Since the upper ends of the inner walls **121**, **121**,... are widened, the flow direction at the upper end area changes for a certain angle towards the outer circumference of the inner vessel **12**. Then, plating solution flows out upwardly from the columnar space **122** and

cylindrical spaces **123**, **123**,... merges at the lower face of the rotary electrode **3**, flowing toward the outside in the diameter direction from the center part along the lower face of the rotary electrode **3**. The plating solution flowing in this manner provides the plating reaction to the wafer **9** mounted to the rotary electrode **3**, thereby providing plating to the wafer **9**.

[0023] The plating solution evenly flows towards the outer circumference part from the center part at the lower face of the rotary electrode **3** by its rotation. In this case, the plating solution flows while providing the plating reaction, and as the plating solution keeps flowing from the center part towards the outer peripheral area, a new plating solution flowing from each of the cylindrical space **123**, **123**,... joins the flow. Therefore, the characteristics of the plating solution, such as concentration, at the lower face of the rotary electrode **3** becomes uniform from the center part to the outer peripheral area.

[0024] Also, the optimal result can be obtained when the flow quantity of the plating solution flowing from each of the columnar space **122** and cylindrical spaces **123**, **123**,... towards the rotary electrode **3** gradually increases from the center part (cylindrical space **122**) of the inner vessel **12** towards the outer circumference. This is because, if the flow quantity in the center side space of the inner vessel **12** is large, it becomes impossible to supply the plating

solution from the peripheral side space towards the rotary electrode **3**.

[0025] Next, the following explains another operational example of this invention. Fig. 6 is a cross-sectional diagram of the plating vessel model of another operational example of this invention. The plating vessel 1 shown in Fig. 6 contains a cylindrical inner vessel in which columns **120**, **120**,..., each having a pie-shaped cross-sectional area containing coaxially formed plural gutter-like inner walls **124**, **124**,..., are continuously formed around the axial line of the rotary shaft **30** of the rotary electrode **3**, providing alternately differentiated diameters of inner walls **124**, **124**,... of the adjacent columns **120**, **120**. With this type of inner vessel **12**, since the diameter of each adjacent inner wall **124**, **124**,... of the columns **120**, **120**,... is differentiated, the plating solution supplied towards the rotary electrode **3** from the cross-sectionally pie-shaped spaces **125**, **125**,... in the adjacent cylinders **120**, **120** reaches the different location in the diameter direction of the rotary electrode **3**. Therefore, the reaction ratio characteristic (such as concentration) of the plating solution flowing along the rotary electrode **3** becomes more uniform from the center area towards the outer circumference. Also, for the plating device having the inner vessel **12** configured as described above, the optimum result can be obtained if the flow quantity of the plating solution flowing /5

toward the rotary electrode **3** from each pie-shaped space **125**, **125**,... gradually increases from the center part of the inner vessel **12** towards the outer peripheral area.

[0026] Next, the plating device based on this invention and two kinds of conventional plating devices (first conventional device configured according to US Patent No. 4102756 and second conventional device having a rotary electrode 3 but not equipped with inner walls **121**, **121**,..) were used to actually conduct Permalloy alloy plating. The results are described below.

[0027] First, the plating condition for this operation are explained. With the plating device of this invention, a Permalloy alloy film was formed as a base by a spattering method beforehand. 2 mm thick Ni metallic net plate was used as the anodic electrodes **4**, **4**,... The plating solution contained 60 g/l of $NiCl_2 \cdot H_2O$ and 1.5 g of $FeSO_4 \cdot 7H_2O$ as metallic ions. Also, boric acid was added as a pH buffer agent to adjust the pH to 3.00 - 3.02. Moreover, to reduce the stress in the film, saccharin natrium was added. In addition, sodium chloride was added as an electrolyte supporter, and lauryl sulfuric acid sodium was added as a surface activation agent. The plating solution temperature was adjusted to the temperature within 23±0.1°C using a electronic thermos device using a Pelletier element. By dividing the inner vessel 12 into 10 layers (space: 40 mm, inner diameter of vessel: 200 mm) from the center part to the outer peripheral part, the flow quantity to the plating solution was

adjusted to the following: 0.02 l/min from the center (first layer), 0.1 l/min (second layer), 0.2 l/min (third layer), 0.4 l/min (fourth layer), 0.5 l/min (fifth layer), 0.6 l/min (sixth layer), 0.7 l/min (seventh layer), 0.9 l/min (eighth layer), 1.0 l/min (ninth layer), 1.1 l/min (tenth layer). Also, almost equal conditions to these were provided to the first and second conventional plating devices for conducting the plating.

[0028] When plating was performed under these conditions, the maximum film distribution and composition distribution of the first conventional device were respectively 7% and 1 wt%. In the case of the second conventional device, the maximum film distribution in the direction towards the outer circumference from the center part was 9%, and maximum composition distribution was 2 wt%. On the other hand, in the case of plating device of this invention, the maximum film distribution in the direction towards the outer circumference from the center part was 2%, and maximum composition distribution was 0.3 wt%. As it is clear from these results, the device based on this invention can provide film thickness and composition more uniformly compared with the conventional device.

[0029] Although a plating vessel 1 was made of an acrylic resin in this operational example, the material of vessel 1 is not limited to an acrylic resin, as it may be made of vinyl chloride resin, polypylene resin, Teflon resin, or the like, or other materials which are non-conductive, non-magnetic and do not react with acid plating

solution. Moreover, although the anodic electrodes 4, 4... of this operational example were made of Ni, the material may be any kind as long as it is the same single metal or alloy for plating.

[0030] [Effects of this Invention]

As explained in detail above, the first plating device of this invention is configured to provide a new plating solution from each space in the cylinder as the plating solution flows from the center part towards the outer peripheral area. Therefore, the characteristics, such as concentration, of the plating solution flowing over the cathodic electrode becomes uniform from the center part towards the outer peripheral part. Moreover, in the case of the second plating device of this invention, since the diameters of the inner walls of adjacent cylinders in the cylindrical body are made different, the plating solutions supplied to the cathodic electrode from the spaces made by adjacent cylinders arrive at the different locations in the diameter direction of the cathodic electrode. Hence, the characteristic, such as concentration, of the plating solution flowing over the cathodic electrode becomes more uniform from the center part towards the outer peripheral area. Furthermore, with the first and second plating methods of this invention, the supply quantity of the plating solution in the spaces in the cylinder body is made greater from the inner side of the cylinder towards the outer side of the cylinder. Therefore, the plating solution supplied from the outer area spaces of the cylinder arrives at the cathodic

electrode without being interfered by the plating solution flowing along the cathodic electrode. Thus, the characteristics, such as concentration, of the plating solution flowing over the cathodic electrode becomes uniform from the center area towards the outer circumference. Therefore, when plating using a rotary cathodic electrode, the characteristics, such as concentration, reaction ratio, etc., of the plating solution flowing along the cathodic electrode becomes uniform, thereby being able to form a film having highly precisely uniform film quality, composition, and thickness on the wafer, which is an excellent benefit.

[Simple Explanation of the Figures]

Figure 1 a cross-sectional diagram illustrating the structural model of the plating device of this invention. Figure 2 is a cross-sectional diagram illustrating a plating vessel model. Figure 3 is a diagram illustrating the back face of a rotary electrode. Figure 4 is an enlarged cross-sectional diagram illustrating the essential area of a rotary electrode. Figure 5 is a diagram illustrating the flow of the plating solution in the inner vessel. Figure 6 is a cross-sectional diagram of a plating vessel model of another operational example of this invention.

[Explanation of Keys]

3...Rotary electrode; 4...Cathodic electrode; 9...Wafer; 12...Inner vessel; 30...Rotary shaft; 120...Cylinder; 121,

124...Inner wall; 122...Cylindrical space; 123...Circular column space; 125...Pie-shaped space

Figure 1

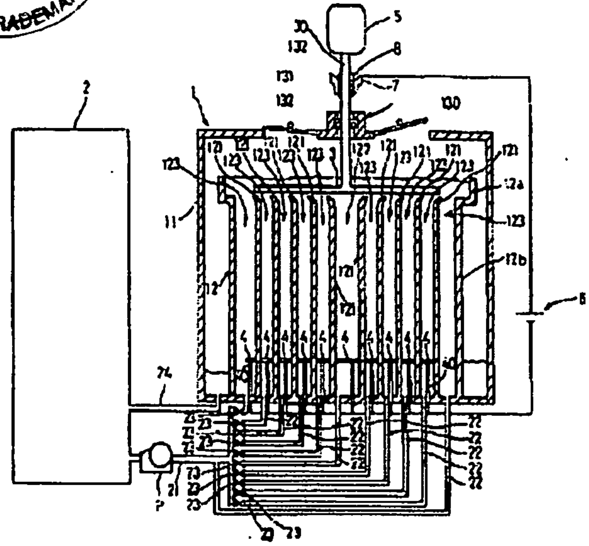

Figure 3

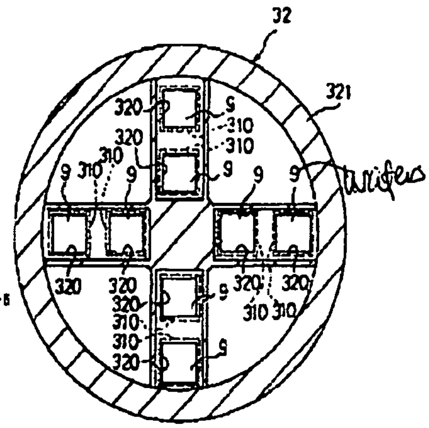

Figure 5

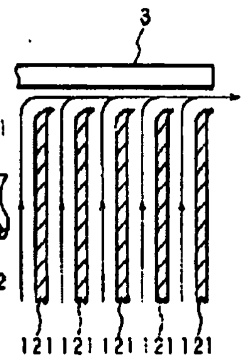

Figure 4

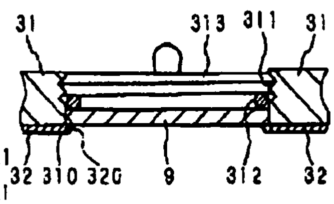

Figure 2

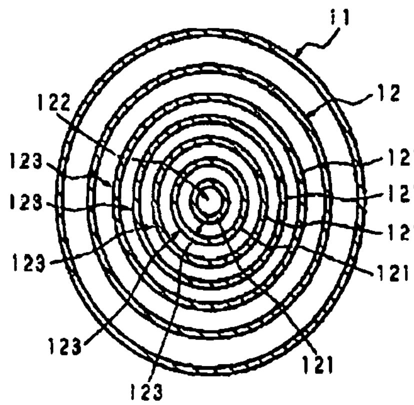

Figure 6